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Vernon C. Bleich

*University of Nevada, Reno, [vcbleich@gmail.com](mailto:vcbleich@gmail.com)*

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## Abnormal Coloration in Bighorn Sheep (*Ovis canadensis*)

Vernon C. Bleich

*Department of Natural Resources and Environmental Science, University of Nevada Reno,  
Reno, NV 89557, vcbleich@gmail.com*

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Reports of abnormal coloration in wild vertebrates are encountered frequently in the literature. Abnormal white coloration manifests itself as albinism or leucism, and those terms are often used interchangeably, albeit erroneously (Curatolo 1979; McCardle 2012). Albinistic individuals are characterized by a complete lack of pigmentation in the skin and hair and have pink eyes; leucistic individuals (Fig. 1), however, are deficient in pigmentation and are white in color, but exhibit pigmented skin and eyes that are normally colored or blue (Abreu et al. 2013 for review). Leucism is a double-recessive trait (Cruickshank and Robinson 1997); hence, normally colored parents have the potential to produce leucistic offspring, but the genetics of albinism should not be confused with the genetics of leucism (Searle 1968).

Piebaldism involves a lack of pigmentation (Abreu et al. 2013) in some parts of the body, and piebald individuals are characterized by normally colored eyes (Fertl and Rosel 2002; Acevedo and Aguayo 2008). Miller (2005) noted that piebaldism has been referred to as partial albinism by some investigators, whereas others have not considered the differences between piebaldism and leucism; thus, the terminology associated with reports of abnormally pigmented animals frequently is confounded (Abreu et al. 2013). Melanistic individuals exhibit dark or even black pelage or appendages resulting from the excessive deposition of melanin, and this condition occurs less frequently than does albinism (Sage 1963).

Shackleton (1985) had reported an absence of records of abnormal coloration in bighorn sheep (*Ovis canadensis*) despite published reports of white-colored individuals (Jones 1958; Hansen 1965a; Cooper 1974; O'Connor 1974; Wilson et al. 1975; McQuivey 1975, 1978; Jones 1980). Individuals exhibiting piebaldism also had been previously described (Hansen 1965a, 1965b), as had melanistic bighorn sheep (O'Connor 1974) and others whose coloration was described by Bunch and Nguyen (1982) as “melanistic black”. Similar to Shackleton’s (1985) report, McCardle (2012) did not include any records of white, albinistic, or leucistic bighorn sheep in a much more recent review.

My interest in this subject dates to 1976—when I learned that  $\geq 2$  white-colored individuals had been seen in the Clark Mountain Range, San Bernardino County, California—and I have since then recorded all records of abnormally colored bighorn sheep that I became aware of. I also used several web-based bibliographic databases (EBSCOhost, JSTOR, Google Scholar, Harzing’s Publish or Perish) and a web-based search engine (Google) to search for words or phrases (albinistic, leucistic, piebald, melanistic, pelage color, etc.) specific to abnormal coloration in bighorn sheep and reviewed results of those searches for references to abnormal coloration in that species. Additionally, I contacted numerous bighorn sheep biologists and other colleagues in the United States and Canada, as well as guides, outfitters, and hunters that had accumulated extended periods of time in the field, and queried each regarding observations of abnormally colored bighorn sheep. Finally, a simple questionnaire was distributed via e-mail to members and affiliates of the Northern Wild Sheep and Goat Council or the Desert Bighorn Council.



Fig. 1. Leucistic female and normal female bighorn sheep and leucistic male and normal male bighorn sheep in the Clark Mountain Range, San Bernardino County, California, 25 September 1998. Photograph by George C. Kerr, Society for the Conservation of Bighorn Sheep, used with permission.

In western North America, bighorn sheep occupy suitable habitat in two Canadian provinces, 5 states in Mexico, and 15 of the contiguous United States. I carefully reviewed information from throughout the range of that species, including descriptions obtained from the literature or from electronic references, and the photographs, electronic images, or detailed descriptions provided by respondents. When information or the quality of an image was sufficiently detailed, I determined if individuals described either as ‘white’ or ‘albino’ were leucistic or albinistic. In addition, I reviewed the results of waterhole counts, aerial surveys, and other aerial events conducted from 1976 to 2009 by personnel from the California Department of Fish and Game (CDFG) or Bureau of Land Management (BLM) in the Nopah Range, Inyo County, California and the Kingston, Mesquite, and Clark Mountain ranges, San Bernardino County, California—areas from which leucistic bighorn sheep previously had been reported. I also reviewed results of aerial surveys of the Avawatz Mountains, San Bernardino County, an area of interest because the Southern Piute word *avawatz* implies “white sheep” (Werner 1951).

Contrary to information provided by Shackleton (1985) and McCardle (2012), observations of leucistic, melanistic, or piebald bighorn sheep have, for many years, been reported from throughout the range of the species (Table 1). In addition to the reports published prior to the reviews of Shackleton (1985) and McCardle (2012), abnormally colored bighorn sheep have now been described from  $\geq 30$  geographic areas from British Columbia southward to Baja California Sur, and as far east as North Dakota. Further, white coloration has been reported among four

Table 1. Locations of reported observations of unique color morphs of bighorn sheep (*Ovis canadensis*) in North America. This compilation almost certainly does not include every geographic area from which color morphs have been reported, but it does establish the widespread distribution of leucistic (L) or piebald (P) bighorn sheep, and those described as 'albino' ('A') or simply as 'white' ('W') by the reporting party. The sex(es) of the bighorn sheep seen appear parenthetically; if not indicated, sex was not determined or otherwise was not available.

Location	Trait <sup>1</sup> (Sex)	Source
Clark Mountain Range, CA	'W'	R. Campbell, Society for the Conservation of Bighorn Sheep
	'L' (♂, ♀)	V. Bleich, R. Weaver; California Department of Fish and Game (CDFG; multiple observations)
	L	McQuivey (1978; leucism determined from McQuivey's [1975, 1978] published descriptions)
Kingston Range, CA	'W' (♀)	J. Jaeger (University of Nevada, Las Vegas; in litt.)
Nopah Range, CA	L (♂)	Yearling captured on 13 November 1989 by R. Clark (CDFG) and W. Boyce (UC Davis)
Stateline Hills, CA and NV	'L' (♂)	McQuivey (1978); J. Jaeger (in litt.) A. Pauli (CDFG; in litt.)
Cottonwood Mountains, CA <sup>2</sup>	'W'	J. Wehausen, White Mountain Research Station (personal communication)
Spring Mountains, NV	'W' (♂, ♀)	Hansen (1980); J. Rozich, U.S. Forest Service (USFS); C. Stevenson, Nevada Division of Wildlife (NDOW); P. Cummings, NDOW; B. Jefferson, Fraternity of the Desert Bighorn; J. Zenz, bighorn sheep outfitter (each via personal communication); NWRBC (1995)
	'A' (♀)	Cooper (1974)
	'A', 'W'	McQuivey (1975)
	'L' (♂, ♀)	McQuivey (1978) (leucism determined from McQuivey's published descriptions)
	'L' (♂),	V. Clark (personal communication; leucism determined from photograph)
	L (♂, ♀)	<a href="http://www.birdandhike.com/Wildlife/Mamm/08Art/05_Bov/Ovis_can/RedRocks/WhiteSheep/_Ovi_can_white.htm">http://www.birdandhike.com/Wildlife/Mamm/08Art/05_Bov/Ovis_can/RedRocks/WhiteSheep/_Ovi_can_white.htm</a> (leucism determined from photograph)
	L (♂)	<a href="http://www.fineartamerica.com/featured/desert-bighorn-sheep-white-phase-donnie-barnett.html">www.fineartamerica.com/featured/desert-bighorn-sheep-white-phase-donnie-barnett.html</a> (leucism determined from photograph)
	L (♂)	<a href="http://www.summitpost.org/white-lamb-with-normal-bighorns/355935">www.summitpost.org/white-lamb-with-normal-bighorns/355935</a> (leucism determined from photograph)
	L (♂)	<a href="http://www.aroundthebendfriends2.blogspot.com/2012/03/white-bighorn-32412.html">www.aroundthebendfriends2.blogspot.com/2012/03/white-bighorn-32412.html</a> (leucism determined from photograph)
	L (♂)	<a href="http://www.aroundthebendfriends2.blogspot.com/2012/03/white-bighorn-32412.html">www.aroundthebendfriends2.blogspot.com/2012/03/white-bighorn-32412.html</a> (leucism determined from photograph)
Near Las Vegas, NV	'A' (♂)	O'Connor (1974; sex was inferred from O'Connor's description)
Muddy Mountains, NV	'W'	McQuivey (1978)
El Dorado Mountains, NV	'W'	McQuivey (1978)
Pintwater Range, NV	'P', 'W' (♂, ♀)	Hansen (1965a)
	'W'	E. Pribyl, Fraternity of the Desert Bighorn (personal communication)
Highland Range, NV	'W'	E. Pribyl (personal communication)
Hiko Range, NV	'W' (♂)	J. Zenz; C. Stevenson; P. Cummings; E. Pribyl (each via personal communication)

Table 1. (Continued).

Location	Trait <sup>1</sup> (Sex)	Source
Ruby Mountains, NV	L (♂)	L. Spradlin (personal communication; leucism determined from photograph)
Sierra Ancha, AZ	'L' (♂, ♀)	D. Darveau, Arizona Game and Fish Department (AZGFD; personal communication)
Near Roosevelt Lake, AZ	L (♂, ♀)	<a href="http://www.coueswhitetail.com/forums/topic/18168-some-white-bighorn-sheep/">www.coueswhitetail.com/forums/topic/18168-some-white-bighorn-sheep/</a> (probably leucistic as determined from photographs)
Silver Bell Mountains, AZ	'P' (♂)	D. Aubuchon, AZGFD; B. Brochu, AZGFD (each via personal communication)
Little Harquahala Mtns, AZ	'L' (♀)	M. Brown (AZGFD, personal communication; leucism determined from description)
Grand Canyon, AZ	L (♀)	<a href="http://archive.library.nau.edu/cdm/singleitem/collection/cpa/id/3686/rec/11">archive.library.nau.edu/cdm/singleitem/collection/cpa/id/3686/rec/11</a> (leucism determined from photograph)
	'W' (♀)	M. Jorgensen, California Department of Parks and Recreation (personal communication)
	L (♂)	M. Jorgensen (personal communication; leucism determined from description of image)
Wind River Range, WY	L (♂)	Ferris (2013; leucism determined from photograph)
	'W' (♂)	K. Hurley, Wyoming Game and Fish Department (personal communication)
Thoroughfare Canyon, WY	'W'	J. Stradley and K. Alt, Montana Department of Fish, Wildlife and Parks (personal communication)
Skaha Lake, BC, Canada	L (♀)	A. Reid, British Columbia Ministry of Forests, Lands and Natural Resource Operations (personal communication; leucism determined from photograph)
	L (♀)	<a href="http://olivedailynews.com/steep-feeding/">http://olivedailynews.com/steep-feeding/</a> (leucism determined from photograph)
Badlands, ND	'W'	Morsette (1996)
T. Roosevelt National Park, ND	'L'	B. Wiedmann, North Dakota Game and Fish Department (personal communication)
	'W'	<a href="http://www.minotdailynews.com/page/content.detail/id/571621/Of-black-squirrels-and-white-bighorns.html?nav=5012">www.minotdailynews.com/page/content.detail/id/571621/Of-black-squirrels-and-white-bighorns.html?nav=5012</a>
Not disclosed	'W'	Jones (1980)
Bitterroot Range (Unit 20A), ID	L (♀)	K. Hurley (personal communication; leucism determined from photograph)
Sheep Mountain (Unit 36A), ID	'W' (♂)	K. Hurley (personal communication)
	'W' (♀)	J. Walters and M. Johnson, USFS (personal communication)
Lemhi Range, ID	'L'	J. Walters and M. Johnson, USFS (personal communication)
West of Abajo Mountains, UT	'L' (♀)	B. Crompton, Utah Division of Wildlife Resources (UDWR; personal communication)
Bookcliff Mountains, UT	'P' (♂)	R. Thacker, UDWR (personal communication)
San Juan River Canyon, UT	'P' (♂)	G. Wallace, UDWR (personal communication)

Table 1. (Continued).

Location	Trait <sup>1</sup> (Sex)	Source
Antelope Island, UT <sup>3</sup>	'L' (♂) L (♂)	R. Robinson, UDWR (personal communication) <a href="https://www.facebook.com/wildlifecaptureequipment/photos/a.1914961962062962.1073741852.1473946379497858/1914962002062958/?type=3&amp;theater">https://www.facebook.com/wildlifecaptureequipment/photos/a.1914961962062962.1073741852.1473946379497858/1914962002062958/?type=3&amp;theater</a> (leucism determined from photograph)
Sierra de San Pedro Martir, Baja California, Mexico	'W'	Wilson et al. (1975)

<sup>1</sup>Single quotation mark around a trait indicates it was described by the original observer(s); an absence of quotes indicates the designated trait was assigned by V. Bleich from information available from, or provided by, the source.

<sup>2</sup>Riverside County.

<sup>3</sup>UDWR personnel translocated this individual, a male lamb, from Antelope Island to the Canyon Mountains, Utah, in January of 2016.

of the five clades (*O. c. canadensis*, *O. c. cremnobates*, *O. c. nelsoni*, and *O. c. mexicana*) of bighorn sheep recognized by Buchalski et al. (2016). Reports of piebald or melanistic individuals were, however, much less common than reports of white-colored animals (Table 1). Although there likely are additional records of abnormal coloration in bighorn sheep not reported herein, this paper corrects the omissions of Shackleton (1985) and McCardle (2012) and, hopefully, will stimulate others to record additional observations of anomalous coloration in that iconic species.

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